U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Digital maps of low- to moderate-temperature geothermal springs and wells in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project

by
Pamela D. Derkey[1] and Bruce R. Johnson[1]

Open-File Report 95-689

Prepared in cooperation with the U.S. Forest Service and Bureau of Land Management.

1995

[1] Spokane, WA 99201

Table of Contents

List of Figures

List of Plates

(available in HPGL2 digital plot file format at a scale of 1:2,000,000 on the Internet)

Acknowledgements

This product would not exist without the input of the many geoscientists whose work has previously been compiled to create datasets of geothermal water information. We had the simpler task of converting our predecessors' digital spreadsheet datasets to a single unified geographic information system format. We acknowledge the work of those geoscientists and the agencies that supported their compilations. Those agencies include the U.S. Geological Survey, the U.S. Department of Energy, the California Division of Mines and Geology, the Idaho Geological Survey, the Montana Bureau of Mines and Geology, the Nevada Bureau of Mines and Geology, the Oregon Department of Geology and Mineral Industries, the Oregon Institute of Technology Geo-Heat Center, the Utah Geological and Mineral Survey, and the Washington State Department of Natural Resources. We particularly acknowledge Patrick Geehan, the Bureau of Land Management project coordinator for the Interior Columbia River Basin Ecosystem Management Project. Pat had the foresight to recognize that geology could contribute in many ways to ecosystem management and sought input from the U.S. Geological Survey. We also gratefully acknowledge Patrick Muffler for his review of this report.

Introduction

This report is one in a series of digital maps, data files, and reports generated by the U.S. Geological Survey (USGS) to provide geologic information for the Interior Columbia Basin Ecosystem Management Project (ICBEMP), a U.S. Forest Service and Bureau of Land Management interagency project. The various digital maps and data files that were provided by the USGS and that are available in this and other reports are being used in a geographic information system (GIS)-based ecosystem assessment. The assessment will include a comprehensive analysis of past, present, and future ecosystem conditions within the general area of the Columbia River Basin east of the Cascade Mountains.

The Interior Columbia Basin Ecosystem Management Project

In January of 1994, the Chief of the U.S. Forest Service (USFS) and the Director of the Bureau of Land Management (BLM) initiated what was then called the Eastside Ecosystem Management Project to “develop a scientifically sound and ecosystem-based strategy for management of eastside forests.” The project was further directed to, “develop an ecosystem management framework and assessment for land administered by the Forest Service and the Bureau of Land Management on those lands east of the Cascade crest in Washington and Oregon and within the interior Columbia River Basin.” The driving force behind the project was the need to develop a strategy for dealing with anadromous fish (primarily salmon) habitat and watershed conservation in eastern Oregon and Washington. Subsequently, when it became clear that similar strategies were needed for anadromous fish in the

remainder of the Columbia River Basin (particularly in Idaho and Montana), the project was extended to include all of the Columbia River drainage basin in the United States, east of the Cascade Mountain divide plus the remainder of southeastern Oregon which is not within the drainage basin (fig. 1). At that time, the project was renamed the Interior Columbia Basin Ecosystem Management Project (ICBEMP).

The ICBEMP is producing scientific assessments of current and historic landscape conditions; of aquatic and terrestrial habitat, species distributions, and populations; and of economic and social conditions. The project is also producing scientific assessments of the potential future conditions and possible tradeoffs likely to result from a range of possible disturbances and management practices on public lands in the basin. Although scientific assessments are being conducted for the entire basin, management decisions that are based on the assessments will apply to public lands (USFS and BLM) only.

The goal of the ICBEMP management strategy is to provide management tools which can be used to sustain or restore ecosystem integrity and to promote products and services desired by society over the long term. The management strategy is intended to provide tools to balance ecosystem conditions, resource uses, and competing values of ecosystem users. The intent of the project is to understand the ramifications of past, present, and future management practices and man-made or natural disturbances both in the area subject to the management practice or disturbance and in areas which may be remote, in time and/or space.

The project is organized around two teams, the Science Integration Team and the Environmental Impact Statement Team, with overlapping membership. Both teams are further sub-divided into staff areas (sub-teams of subject experts) including: landscape ecology, aquatic/riparian, terrestrial, forest policy and economics, and social sciences. Many staff scientists work on both the Science Integration Team and the Environmental Impact Statement Team.

Specific objectives of the project are:

- To conduct a broad scientific assessment of the resources within the interior Columbia River basin to characterize and assess landscape, ecosystem, social, and economic processes and functions and describe probable outcomes of various management practices and trends.
- To develop an ecosystem management framework that includes principles and processes which may be used in a National Environmental Protection Act (NEPA) process to develop management direction for federal agencies at all levels within the basin.
- To write an Eastside Environmental Impact Statement (EIS) proposing a broad array of alternative strategies for an area that encompasses ten national forests and portions of four BLM districts in eastern Washington and Oregon (fig. 1).
- To write an Upper Columbia River Basin EIS with a similar array of alternative strategies for an area that encompasses lands administered by

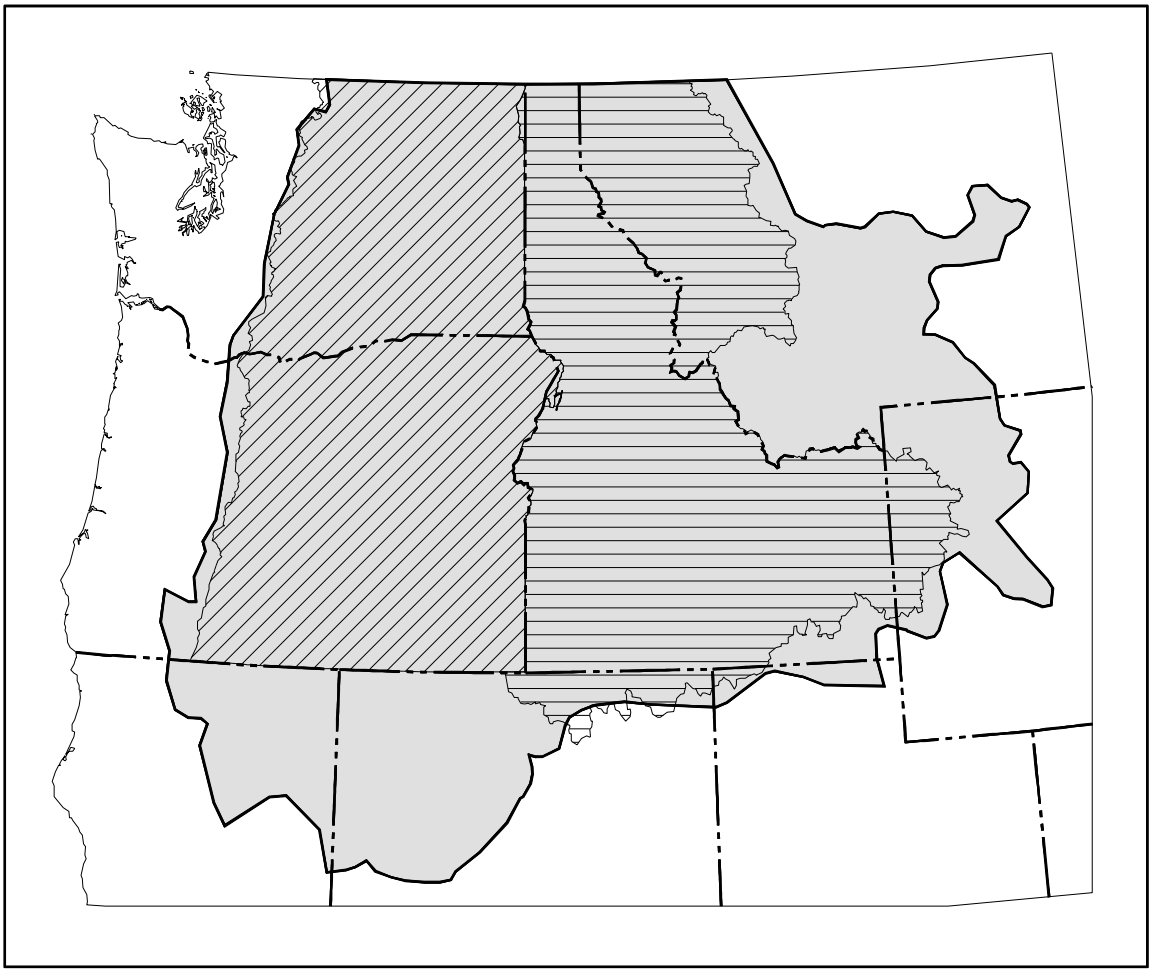

Figure 1. Index map showing the geographic extent of the Interior Columbia Basin Ecosystem Management Project. Shown on the map are the Landscape Characterization Area (grey shading) which is the study area used by most Science Integration Team staff areas, the Eastside EIS area (diagonal hatching), and the Upper Columbia EIS area (horizontal hatching).

- the BLM and USFS in Idaho, western Montana, Wyoming, Utah, and Nevada within the Columbia River Basin (fig. 1).
- To conduct a scientific evaluation of issues and alternatives identified through the NEPA scoping process for the Eastside EIS.

The ICBEMP is an intense, short term project to develop several regionally-consistent, land-management alternatives. These alternatives, derived from basin-wide analyses of highly generalized data, will form a framework for land-management decisions at the local level. This framework will be modified as better data and understanding of the basin are developed. Under the project, a flexible, basin-wide, digital database will be developed that will evolve and improve as higher resolution data become available. All data are being collected in a GIS-compatible format for digital display, analysis, and distribution. Information on the availability of all digital data sets, paper maps, and other reports generated by the ICBEMP can be obtained from:

Interior Columbia Basin Ecosystem Management Project
ATTN: Cindy Dean
112 E. Poplar Street
Walla Walla, WA 99362
(509) 522-4030

or from:

Bureau of Land Management
ATTN: Becky Gravenmeier, OR99.2
Oregon - Washington State Office
P.O. Box 2965
Portland, OR 97208
(503) 952-6273

Project Extent and Scale

The scope and extent of the project area varies as a function of the objective. The scientific assessment, for example, includes all lands, not just those that are federally managed. This objective is focused on the Columbia River Basin but is not strictly limited to the actual drainage basin boundaries. Moreover, some scientific assessment subject sub-teams, by necessity, have extended their work beyond the limits of the formal project because factors such as wildfires and wildlife migration are not limited by drainage divides or political boundaries. Most subject sub-team project areas are restricted to the Landscape Characterization boundary developed by the Landscape Ecology group (fig. 1). The scientific assessment is primarily based on information suitable for compilation at a scale of 1:1,000,000.

U.S. Geological Survey Involvement

In June, 1994, the USGS was asked to provide estimates on the value of undiscovered mineral resources for the Columbia basin. In the course of discussions with members of various sub-teams from both project teams, it became apparent that additional earth science information was also highly

relevant to the assessment of historic, current, and future ecological, economic, and social systems, and that the USGS could provide this information in a digital format. Within the ICBEMP's tight schedule (7 months from the USGS start date until the information had to be available to the rest of the Science Integration Team), the USGS was able to provide basin-wide, integrated, digital information about bedrock lithology, rock chemistry, potential animal habitat, stream sediment geochemistry, volcanic and earthquake hazards, and mineral resources. The USGS was able to provide digital information about geothermal waters at the ICBEMP's request at a slightly later date.

Bedrock lithology information is summarized in Johnson and Raines (1995). The bedrock chemistry information will be summarized in Raines, Johnson, Frost, and Zientek (1996). Potential animal habitat information will be summarized in Frost, *et al.* (1996), and stream sediment geochemistry is summarized in Raines and Smith (1995). Digital hazards information was derived from Algermissen, *et al.* (1990) and Hoblitt, Miller, and Scott (1987). Mineral resources information is or will be summarized in Bookstrom, Raines, and Johnson (1995), Box, *et al.* (1996); Bookstrom, Zientek, *et al.* (1996); and Zientek, *et al.* (1996). Low- to moderate-temperature geothermal waters data was derived from Black (1994); Blackett (1994); Dansart, Kauffman, and Mink (1994); Garside (1994); Metesh (1994); Schuster and Bloomquist (1994); and Youngs (1994) and is integrated and summarized in this report. Considerably more information was identified as potentially useful to the ICBEMP, but additional integrated digital products could not be provided for the entire study area within the time frame of the assessment.

Data Sources, Processing, and Accuracy

The sources of digital data for the geothermal springs and wells maps (plates 1, 2 and 3) were individual geothermal reports for the states of California (Youngs, 1994), Idaho (Dansart, Kauffman, and Mink, 1994), Montana (Metesh, 1994), Nevada (Garside, 1994), Oregon (Black, 1994), Utah (Blackett, 1994), and Washington (Schuster and Bloomquist, 1994). Digital geothermal data for the state of Wyoming were not available and, thus, not included in this report. Locations of rivers and perennial streams used on the geothermal springs and wells maps were obtained from USGS 1:2,000,000 scale Digital Line Graphs (U.S. Geological Survey, 1990).

Digital geothermal data from all the states except Washington (which provided ARC/INFO GIS) were converted from a variety of spreadsheet programs into dBase IV database formatted files (DBF files) using Excel 5.0. The DBF files were converted into spatial GIS datasets for each state using PC ARC/INFO 3.4.2 and then exported to a SUN/ARC/INFO platform where they were combined to produce an integrated low- and moderate-temperature geothermal waters GIS for the Pacific Northwest.

The states' digital data represent the best and most recent inventories for low- and moderate-temperature (<150^{o} C) geothermal waters in each state.

The states' work was funded by the U.S. Department of Energy's (DOE) Geothermal Division as part of DOE's Low-Temperature Geothermal Resource and Technology Transfer Program in response to a direct appropriation from Congress in 1991 to encourage the development of low-temperature geothermal waters. The following section briefly describes the geothermal spring and well maps of the Pacific Northwest (plates 1-3).

Low- and Moderate-Temperature Geothermal Springs and Wells

Digital data included in this GIS include geothermal site name, state, county, site type, latitude and longitude, water temperature (^{o} C), depth of well (m), flow rate (lpm), and pH (see Appendix A for documentation of item entries). Water chemistry was not included in this GIS product due to time constraints in releasing a product for the ICBEMP. There is a total of 6,155 records in this GIS with each record representing a single sample from one collection point. More than one record may exist for a site due to multiple sampling over time; however, the states generally selected one sample record to best represent a single site for their compilation.

The geothermal spring and well maps for the ICBEMP study area (plates 1, 2, and 3) show locations of geothermal springs and wells in the Pacific Northwest with low to moderate water temperatures (less than 150^{o} C), in addition to a few representative sites indicating the presence of hotter thermal waters. Generally, sites were included in the states' data sets if the water temperature ranged from at least 10^{o} C above the mean annual surface temperature up to an upper limit of 150^{o} C.

Geothermal spring localities may be significant to identifying and understanding site-specific flora and fauna: certain plant and animal species are endemic to geothermal spring areas and may impact the management of the area. Warm water (less than 150^{o} C) from geothermal springs and wells is currently being used for a variety of applications, including space heating, agriculture, aquaculture, and recreation (and provides an economic impact on the local areas).

Known Geothermal Resource Areas (KGRAs), areas designated as having the potential to generate electricity from high- or moderate-temperature geothermal waters, are not delineated in this report. KGRAs are shown in Muffler (1979); however, some areas have been added or withdrawn or had boundaries revised since then (Youngs, 1994; Anne E. Gartner, personal comm., 1995). Gartner, Guffanti, and Muffler of the U.S. Geological Survey have commenced work on a digital GIS to delineate current KGRA boundaries in the western United States, but their work is still in progress (Anne E. Gartner, personal comm., 1995).

Temperature

The temperature value given in this GIS represents surface temperature for the thermal springs, but may represent either surface temperature or bottom-hole temperature for the wells. There are 127 records

for sites with temperatures greater than 8° C and less than 20° C. There are 5,897 records for sites with temperatures ranging from 20° C to less than 150° C. Some states included sites with temperatures greater than 150° C to represent those areas where higher temperatures exist: there are 28 records with a recorded temperature greater than or equal to 150° C. Finally, there are 103 records for sites where the temperature was not recorded, but were considered by the state to be a thermal site and may have been identified as "warm" or "hot" in the original data sets.

Site Type

Entries for 'site type' were not generalized from the states' original entries so as to retain as much of the original information as possible. Most states used 'well' or 'spring' as an entry; however, a 'spring' entry in the Washington data set indicated that the site might be a spring, spring system, lake, lava dome, or an area of fumeroles; California's data set qualified the types of wells; and Utah's data set used queries to qualify entries (i.e., 'spring?' and 'well?'). A few other miscellaneous site type entries were used by some states, including mine, drain, tunnel, and collector. There are 5,039 records for sites that are wells or probable wells, 1,109 records for sites that are springs or probable springs, and 7 records that represent other miscellaneous site types.

Flow and pH

Flow was measured for 1,436 records and ranged from 0.1 to 2,550,000 liters per minute. The pH ranged from 2.3 to 10.82 for the 1,908 records for which pH was measured.

Obtaining Digital Data

The digital files which were used to make the geothermal spring and well maps are available as a single GIS coverage and associated data files. These data and map images are maintained in the map projection used for all ICBEMP products:

Projection:	Albers Equal Area
1st Standard Parallel:	43° N
2nd Standard Parallel:	48° N
Central Meridian:	117° W
Origin of Projection:	41° N
Y-offset (false easting):	700,000 meters

To obtain copies of the digital data, do one of the following:

1. Download the digital files from the USGS public access World Wide Web site on the Internet:

URL = http://wrgis.wr.usgs.gov/docs/northwest_region/ofr95-689.html

or
Anonymous FTP from: **wrgis.wr.usgs.gov,** in the directory:

pub/geologic/northwest_region/misc/ofr95-689

These Internet sites contain the geothermal GIS point coverage in Arc/Info Export file format (geotempnw.e00) as well as the associated data files and Arc/Info macro programs which are used to plot the map at a scale of 1:2,000,000. Use of this data requires a GIS that is capable of reading Arc/Info Export formatted files and a computer capable of reading UNIX ASCII files. To use this file on a DOS computer, it must be put through a unix-to-dos filter. Or,

2. Obtain the digital files from the ICBEMP project office. Contact information is given in the section, **The Interior Columbia Basin Ecosystem Management Project**, above.

Obtaining Paper Maps

Paper copies of the geothermal springs and wells maps are not available from the USGS at this time. However, with access to the Internet and access to a large-format color plotter, a 1:2,000,000-scale paper copy of the map can be made, as follows:

1. Download the digital version of the complete map from the USGS public access World Wide Web site on the Internet.

URL = http://wrgis.wr.usgs.gov/docs/northwest_region/ofr95-689.html

or
Anonymous FTP from: **wrgis.wr.usgs.gov,** in the directory:

pub/geologic/northwest_region/misc/ofr95-689

These Internet sites contain two files, **spring2m.hp** and **well2m.hp** which are in HPGL2 graphics language

2. These files can be plotted by any large-format graphics plotter which can interpret the HPGL2 language. The finished plots are 27 by 38 inches.

Paper copies of the map can also be created by obtaining one of the versions of the digital files as described above, and then creating a plot file in a GIS.

References Cited

Algermissen, S. T., Perkins, D. M., Thenhaus, P. C., Hanson, S. L., and Bender, B. L., 1990, Probabilistic earthquake acceleration and velocity maps for the United States and Puerto Rico: U.S. Geological Survey Miscellaneous Field Studies Map, MF-2120, scale 1:7,500,000.

Black, Gerald L., 1994, Digital data and selected texts from low-temperature geothermal database for Oregon: Oregon Department of Geology and Mineral Industries, Open-File Report O-94-9, 13 p. and 1 computer disk.

Blackett, Robert E., 1994, Low-temperature geothermal water in Utah: a compilation of data for thermal wells and springs through 1993: Utah Geological Survey, Open-File Report 311, 74 p., 2 plates, and 1 computer disk.

Bookstrom, A.A., Raines, G.L., and Johnson, B.R., 1995, Digital mineral resource maps of phosphate and natural aggregate for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-681, 24 p. plus 4 plates.

Bookstrom A. A., Zientek, M. L., Box, S. E., Derkey, P. D., Elliott, J. E., Frishman, David, Ashley, R. P., Evarts, R. C., Stoeser, D.B., Moyer, L. A., Cox, D. P., and Ludington, Steve, 1996, Status and metal content of significant metallic mineral deposits in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-688, 93 p. plus 1 plate.

Box, S. E., Bookstrom, A. A., Zientek, M. L., Derkey, P. D., Ashley, R. P., Elliott, J. E., and Peters, S. G., 1996, Assessment of undiscovered mineral resources in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-682, 415 p.

Dansart, William J., Kauffman, John D., and Mink, Leland L., 1994, Overview of geothermal investigations in Idaho, 1980 to 1993: Idaho Water Resources Research Institute, Research Technical Completion Report, 79 p., 1 plate, and 1 computer disk.

Frost, T.P., Raines, G.L., Almquist, C., and Johnson, B.R., 1996, Digital maps of possible bat habitats for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-683, 20 p.

Garside, Larry J., 1994, Nevada low-temperature geothermal resource assessment: 1994: Nevada Bureau of Mines and Geology, Open-File Report 94-2, 84 p., 1 plate, and 1 computer disk.

Hoblitt, R. P., Miller, C. D., and Scott, W. E., 1987, Volcanic hazards with regard to siting nuclear power plants in the Pacific Northwest: U.S. Geological Survey Open-File Report 87-297, 196 p.

Johnson B. R. and Raines, G. L., 1995, Digital map of major lithologic bedrock units for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-680, 36 p. plus 2 plates.

Metesh, John, 1994, Geothermal resources of Montana: Montana Bureau of Mines and Geology, unpublished report submitted to Oregon Institute of Technology Geo Heat Center and to University of Utah Research Institute, 51 p. and 1 computer disk.

Muffler, L.J.P. (ed.), 1979, Assessment of geothermal resources of the United States--1978: U.S. Geological Survey, Circular 790, 163 p. plus 1 plate.

Raines, G.L., Johnson, B. R., Frost, T.P., and Zientek, M.L., 1996, Digital maps of compositionally classified lithologies derived from 1:500,000 scale geologic mapping for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-685, 28 p.

Raines, G.L. and Smith, C.L., 1995, Digital maps of National Uranium Resource Evaluation (NURE) geochemistry for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-686, 22 p.

Schuster, J. Eric, and Bloomquist, R. Gordon, 1994, Low-temperature geothermal resources of Washington: Washington Division of Geology and Earth Resources, Open File Report 94-11, 53 p. and 1 computer disk.

U.S. Geological Survey, 1990, 1:2,000,000-Scale Digital Line Graph (DLG) Data: U.S. Geological Survey, Digital Data Series-4, CDROM.

Youngs, Leslie G., 1994, California low-temperature geothermal resources update - 1993: California Department of Conservation, Division of Mines and Geology, 178 p., 3 plates, and 1 computer disk.

Zientek, M.L., Bookstrom, A.A., Box, S.E., and Johnson, B.R., 1996, Future minerals related activity, Interior Columbia Basin Ecosystem Management Project area: an overview: U.S. Geological Survey Open-File Report 95-687, 30 p.

APPENDIX A: GIS Documentation

Point attribute descriptions for **GEOTEMPNW.PAT** are as follows:

ITEM NAME	START COLUMN	ITEM LENGTH	ATTRIBUTE DESCRIPTIONS
name	17	50	name of geothermal site
state	67	5	2-character state postal code
county	72	16	county name
type	88	15	collector - collector well drain - drain for petroleum or gas well mine - mine spring - spring spring? - probable spring tunnel - dewatering tunnel water well - water well well - well well? - probable well well-CLT - commercial low-T well well-EST - exploratory steam well well-flowing - well with flow well-INJ - injection well well-NLT - noncommercial low-T well well-OIL - petroleum well well-SW - well drilled to control spring flow well-TG - temperature gradient well-X - type not confirmed, but most appear to be high-T exploration wells.
latitude	103	11	N latitude in decimal degrees
longitude	114	11	W longitude in decimal degrees (appears as a negative value)
temp	125	9	recorded temperature in ^{o}C; a '-999' entry indicates temperature was not recorded
depth	134	9	depth (of well) in meters; a '-999' entry indicates depth was not recorded
flow	143	9	flow rate in liters per minute; a '-999' entry indicates flow rate was not recorded
pH	152	6	pH value; a '-99' entry indicates pH was not recorded